2.3 GENERAL SYSTEM CONSIDERATIONS

This section addresses safety and design requirements, safety classification, regulatory requirements, codes and standards requirements, redundancy and separation, and material restrictions.

2.3.1 SAFETY AND DESIGN REQUIREMENTS

According to operational requirements, an air cleaning system may be operated full-time, part-time, or simply held in standby for emergency service. If processes in the building are operated only one or two shifts a day, the designer may have a choice between continuous operation and operation only during those shifts. To ensure satisfactory environmental conditions, pressure boundary leakage must be controlled and the housing must be designed to meet allowable leakage requirements.

Many facilities require standby exhaust or air cleanup systems that are operated only in the event of an emergency or redundant air cleaning facilities that are brought into operation when a parallel online facility is shut down because of failure or for maintenance. When designing standby systems, the engineer must keep in mind the possibility of component, filter, and adsorber deterioration from environmental conditions (e.g., condensation, temperature) even when the system is not in use.

2.3.1.1 DESIGN REQUIREMENTS

The ventilation and air cleaning systems of a building in which radioactive materials are handled or processed are integral parts of the building's confinement. In some cases, these systems may be shut down in the event of an operational upset, power outage, accident, fire, or other emergency. In other cases, they must remain operational to maintain the airflows and pressure differentials between building spaces and between the building and the atmosphere, which are needed to maintain confinement. In some cases, airborne radioactive material may not be a problem until an emergency occurs. In all cases, a particular danger is damage to or failure of the final, downstream HEPA filters (and adsorbers in those facilities where radioactive gases could be released) that constitute the final barrier between the confined space (hot cell, glovebox, room, or building) and the atmosphere or adjacent building spaces. Even if the system can be shut down in the event of an emergency, protection of the final filters must be ensured to prevent the escape of contaminated air to the atmosphere or to occupied spaces of the building.

Consideration must be given (1) to the possible effects of operational upsets, power outages, accidents, fires, and other emergencies on the ventilation and air cleaning systems, including damage to the filters and adsorbers from shock, overpressure, heat, fire, smoke, and high sensible-moisture loading; (2) to the design and arrangement of ducts and air cleaning components to alleviate these conditions; (3) to the available means of switching to a redundant air cleaning unit, fan, or alternate power supply; and (4) to the available methods of controlling the exhaust system during failure conditions. To provide necessary protection to the public and to plant personnel, the air cleaning and ventilation system components on which leakage control depends must remain intact and serviceable under the upset conditions. These components must be capable of withstanding the differential pressures, heat, moisture, and stress of the most serious accident predicted for the facility, without damage or loss of integrity, and must remain operable for the period of time needed to achieve the design objectives (see TABLE 2.1 for environmental design criteria).

The following examples of design basis accidents should be considered when designing an air cleaning system.

- Reactor coolant system LOCA (large and small breaks)
- Seismic Loading [Note that the loads that must be considered when designing the air cleaning system will be different if the system has to remain operational during and after the event, or if the system only has to maintain its structural integrity; i.e., the system does not have to function during and after an event.]
- Fire, smoke, and hot air (see Section 2.4.2.8)
- Tornado/high winds [Tornadoes can cause damage due to a significant pressure drop

(approximately 3 psig, negative) as the tornado passes over the facility. Openings and items (e.g., air cleaning equipment, ductwork, etc.) which are exposed to this pressure transient can collapse if they are not protected by tornado dampers. In addition, tornadoes and high winds can convey missiles that can enter intakes and other unprotected openings and damage safety-related systems and equipment.]

- Internal and external missiles [Internal missiles are usually generated by rotating equipment failure. External missiles are usually generated by a tornado or high wind.]
- High-energy line break (HELB) [These events can affect the air cleaning system environment and/or structural loading (temperature, pressure, humidity, water spray, jet impingement)].
- Active equipment failure [This refers to failure of any equipment that provides an "active" function (e.g., pumps fans, valves, dampers, switches, etc.) and must be relied on to safely shut down the facility and/or maintain it in a safe configuration.]
- Loss of onsite and offsite power [The facility must be designed to be safely shut down and/or maintained in a safe configuration in the event of a loss of onsite and offsite power.]

An excellent overview of the heating, ventilation, and air conditioning (HVAC) requirements for nuclear facilities is contained in the ASHRAE Design Guide.[35]

2.3.1.2 SAFETY CLASSIFICATION

Systems and equipment are classified as either nuclear-safety-related, engineered safety feature (ESF), or non-nuclear-safety-related. In some cases, non-nuclear-safety-related systems and equipment are designated as "Balance Of Plant." Some systems and equipment are referred to as "Important to Safety." This term is not recognized by regulatory agencies and organizations, but certain situations exist where an air cleaning system must perform a function that has lesser requirements than those for a system that is fully nuclear-safety-related. One example is the Technical Support Facility Ventilation Air Cleaning System for commercial nuclear power plants. This plant area is used by plant management and technical support staff to support the operating staff in the control room when unusual events or accidents are taking place. This system is required (1) to be constructed, operated, and tested in accordance with the requirements of U.S. Nuclear Regulatory Commission (USNRC) Regulatory Guide 1.140[40], (2) to be able to provide a positive pressure within the Technical Support Center when it is operational, and (3) to be supplied with Class 1E emergency power. However, the system is NOT nuclear-safety-related.

2.3.1.3 REGULATORY REQUIREMENTS

Air cleaning systems designed for ESF applications at commercial nuclear power plants must meet the requirements of Regulatory Guides 1.52,[17] 1.78,[36] and 1.95,[37] as well as applicable portions of the 's Standard Review Plan. These documents are cited routinely by DOE. In addition, DOE cites numerous of its Orders that have special application to non-power-related reactor activities. Many of these documents are site-specific, and DOE is currently reviewing some of these site-specific documents for possible deletion and replacement (by reference) with consensus codes and standards.

Regulatory Guide 1.52[17] addresses ESF air cleaning system requirements. Regulatory Guide 1.140[49] addresses non-safety-related air cleaning system requirements. Regulatory Guide 1.78 addresses climatic affects and requirements for outside air intakes.

2.3.1.4 CODES AND STANDARDS REQUIREMENTS

Air cleaning systems designed for ESF applications at commercial nuclear power plants must meet the requirements of ASME Standard N509, "Nuclear Power Plant Air Cleaning Units [23] ASME Standard N510, "Testing of Nuclear Air Treatment Systems;"[34] ASME Standard N511, "In-service Testing of Nuclear Air Treatment Systems;"[38] and ASME AG-1, "Code on Nuclear Air and Gas [30] It is good practice to implement the codes and standards referenced above for all nuclear-related air cleaning systems and components.

2.3.1.5 Redundancy and Separation

The ESF systems designed to contain and mitigate design basis accidents must be redundant, and these redundant systems must be physically separated so that damage to one does not cause damage to the other.

Redundancy requires two complete trains of equipment and components. There are cases where ductwork has not been completely redundant. A common space served by the redundant trains, such as control rooms, may not require 100 percent redundancy of the ductwork as long as it can be demonstrated that no common mode failures would render both trains of equipment inoperable.

Separation is required so that postulated accidents such as internal missiles, fire, flood, and HELB cannot render both trains of the redundant system inoperable from the same event. Separation can be achieved by physically locating the trains far enough apart that postulated accidents cannot render both trains inoperable, or by erecting a physical barrier, such a concrete wall, for protection.

2.3.1.6 Material Restrictions

Most nuclear power plants restrict the amount of zinc and aluminum that can be used inside the containment structures. Zinc and aluminum both interact with the spray chemistry of the emergency core cooling systems to produce hydrogen, which can accumulate in the containment and become an explosion hazard in the event of a LOCA. The amounts of these materials must be tightly controlled, and an accurate inventory must be kept when these materials are used inside containment structures.

Since most HVAC and air cleaning systems use galvanized steel for ductwork and equipment housings, alternate materials need to be considered for use inside containment structures. One option is to use stainless steel for ductwork and equipment housings. Stainless steel is expensive, but its advantage is that it does not require any coating to prevent the corrosion or scratching that can occur during repair, maintenance, or testing/surveillance activities. In addition, it is easier to decontaminate than some other materials. Another, less costly option is to use steel and to provide a coating that is compatible with the containment environment. The disadvantage of using coated steel is that it does not hold up well to activities where the ductwork or equipment is subject to high repair, maintenance, or testing/surveillance activities. The coating also must be inspected and repaired when damaged, and this can cause critical time delays during refueling or other time-sensitive activities.

Galvanized steel ductwork can be used successfully outside containment, and at a lower cost than stainless steel. Galvanized steel has many of the same advantages as stainless steel, such as ease of decontamination, and it holds up well in areas that are subject to frequent repair, maintenance, testing, and surveillance activities. One caution should be noted, however: if the galvanized coating is damaged severely or removed, as in cases when welded duct construction is used and when supports are attached by welding, then the damaged areas must be recoated with a zinc-rich paint to prevent corrosion.

2.4 Air Cleaning System Design Considerations for Commercial Nuclear Power Plant Systems

2.4.1 Engineered Safety Feature Systems

For ESF applications, applicable regulations, codes, and standards must be combined with good engineering practice. Ease of maintenance, operability, testability, cleanability, and decontamination also must be carefully considered. In addition, air cleaning systems must be integrated into the overall plant or process design, including monitoring and control requirements. ESF Systems are supplied with assured power from the Plant Class IE emergency electrical power system.